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SOLID FUEL COOKING STOVES
BIBLIOGRAPHY

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SOLID FUEL COOKING STOVES: BIBLIOGRAPHY WITH ABSTRACTS

1. Charcoal – an alternative fuel.
   Dhammika de Silva. (CISIR, Sri Lanka)
   Vidurawa. December 1980.

   Firewood prices in Sri Lanka are increasing because of its scarcity as well as costs of transportation to urban areas. Charcoal with its advantages of clean burning, double the calorific value of wood, economical transportation, ease in storage and handling as well as being energy efficient in use can be a viable alternative to firewood. Since charcoal stoves have an efficiency of about 30%, fuelwood requirements can be nearly halved compared to open fire cooking arrangements by switching over to charcoal produced from wood. The State Timber Corporation has undertaken the task of converting the waste wood from the Mahaveli zone and marketing the product. This reserve is expected to suffice for 8-10 years after which the requirements will have to be met from fuelwood plantations. CISIR is also carrying out research in carbonization of rice husk and straw to be used as a base for producing charcoal pellets and briquettes. Byproducts such as methanol and low heat pyrolitic oils will also be available from this process.

2. Charcoal stove from Sri Lanka.
   Dhammika de Silva.
   Appropriate Technology. 7, 4; March 1981; 22-24

   The charcoal stove described consists of a clay cylinder with a narrow waist and a 50 cm^2 opening at the base for air vent. A removable convex clay grate is located on a step on the inside at the waist. Three equidistant 1 cm ridges run from the upper rim to the inside of the stove

to a depth of 6 cms, and provide space for escape of exhaust gases. Small vessels sit inside the stove and large vessels rest on the rim. The stove rests on a removable clay pan which helps in ash removal. The heat transfer efficiency of the stove is about 30%. A test group of 45 households are reported to have used the stove over a 6 month period and found it convenient for use on a regular basis. Those who had previously used firewood found the charcoal stove more refined while those who had previously used kerosene stoves switched over to the charcoal stove mainly out of economic considerations. (The latter group reported a saving of 30-40 % on their kerosene fuel bill). A prototype stove having better features of reduced heat losses is presently being built.

3. Charcoal stoves (Tanzania): Project summary.
Canada, International Development Research Centre (IDRC).
June 1979. 7p.

A charcoal stove is to be developed with an improved fuel economy that will be appropriate for African conditions. Various models of metal stoves from Africa and clay stoves from Southeast Asia will be obtained for this purpose and their efficiencies determined. Information would be gathered on properties of clay available in Tanzania as well as the advantages of mixing clay with ash. A survey would be carried out to find the various users to which the stove is put and the cooking methods and charcoal consumption for different types of households. Laboratory tests would be carried out to evaluate the performance of the stoves and based on this the main features of the most efficient stoves will be incorporated in a prototype to be made from locally available materials. Several stoves of improved design will be fabricated to assess their performance in actual use and their

acceptability by housewives. This would be done with households previously surveyed and data would be collected by interviews. A report containing information on the design and manufacture of the improved stove, fuel consumption data, production cost and guidelines for extension workers who have the task of introducing stoves to other areas would be prepared.

4. Comparison of metal and clay charcoal stoves: Paper presented to a conference on Energy and Environment in East Africa. Nairobi, Kenya Academy of Sciences. May 1979. Keith Openshaw.
Morogoro, Div. of Forestry, University of Dar-es-Salaam.

The traditional African metal charcoal stove, the clay stove used in Thailand and a modified version of the former have been described. Experiments show that atleast 40% of charcoal and 1/3 of the cooking time be saved by substituting clay stoves in place of metal stoves. A second set of experiments carried out to compare all the three stoves indicate that the Thai clay stove performs the best followed by the modified metal stove and the traditional charcoal stove. The modified stove however, has the advantage of robustness combined with a good performance. Implications of introducing a fuel efficient stove in a place like Africa have been outlined.

5. Cooking at low temperatures: Energy and the requirements.
S.C. Popali and others.
Indian Academy of Sciences. Proc. C. 2, 3; Sept. 1979;331-7

Describes an experiment to determine the energy and temperature requirements for cooking rice, potatoes and green vegetables using a 1 kw electric hot plate and an aluminium vessel 210 mm diameter, 220 mm height.

The energy balance is given by

Energy consumed in cooking = energy input to the electric heater - (Increase in sensible heat of water) - Energy losses to the surroundings).

Results indicate that:

- rice, potatoes and green vegetables can be cooked in a reasonable time of 30 to 45 minutes at temperatures of 80 – 90°C.
- energy required for cooking them is about 0.06 to 0.10 kwh/kg
- energy required for cooking is approximately equal to increase in sensible heat of the same amount of water when it is heated to cooking temperature.
- energy required for cooking increases a little with increase in cooking temperature but cooking time is considerably reduced.
- energy for cooking rice and potatoes is almost the same but cabbage needs a little more energy input.

5. Cooking in the Ungra area: Fuel efficiency, energy losses, and opportunities for reducing firewood consumption.
Howard S. Geller.
Bangalore, Indian Institute of Science, Centre for the Application of Science and Technology to Rural Areas (ASTRA). July 1980. 30p.

Cooking patterns have been studied in a specific location with reference to firewood consumption and cooking efficiency. The cooking efficiency was found to be only 6 %, and the use of aluminium rather than clay pots is shown to correlate with higher efficiencies. Since cooking efficiency correlates well with specific fuel consumption, the latter is suggested as being much simpler to measure and analyse than cooking efficiency. Major energy losses during cooking are attributed to heating of excess air, heat carried away by combustion products, heat transmitted to stove body and floor and the chemical

energy in the charcoal residue. Energy loss due to the evaporation of cooking water is also significant because it represents about 1/3 of the heat transferred to the cooking medium. The efficiency and energy loss results along with the observations regarding the practices related to cooking reveal a number of opportunities and directions for reducing fuel consumption.

7. Cooking stoves: The state of the art.
J. Goldemberg and R.I. Brown.
Sao Paolo, University of Sao Paolo. 1979.

People in rural areas actually use more energy and have to devote a larger fraction of their time, effort and economic means in search of firewood, their main fuel for cooking. Increased fuelwood consumption is largely attributed to open fires having efficiencies as low as 5 % or closed fires with efficiencies of just about 15 %. Methods for improving the efficiency include use of a closed hearth with a limited and controllable intake of air for the combustion, fuels to direct heat to the cooking pots, a chimney to set up a draft and remove unburnt gases. Although some technical information is lacking on the scientific design of woodstoves, enough is known to build stoves more efficient than the ones in present use. Implementation of extension programmes is most important for the successful introduction of improved cooking stoves. Guidelines are given for starting such extension programs. Optimising the heat transfer from the fire to the cooking pot by conduction, convection and radiation are also outlined in the appendix.

8. Designing a test procedure for domestic woodburning stoves.
S. Joseph, and Y. Shanahan.
London, Intermediate Technology Development Group.
November 1980. 23p.

The report gives in detail the information needed to provide an initial assessment of the suitability of a stove design before making and testing and secondly the type of laboratory and field tests required to see that a stove is firstly suited to the required cultural cooking practices and has a better performance than the stoves currently used by the people for whom it is intended. In the laboratory tests, a factor termed as Heat Utilised is recommended as being more useful for evaluating the performance of the stove rather than the usual efficiency formula used in evaluating the performance of a boiler. Two values of heat utilized are obtained, one which includes the heat used in evaporating the cooking water and another which exclues this when evaporation is not a necessary part of the cooking process.

Designing stoves for third world countries.
Helen Gould and Stephen Joseph.
London, Intermediate Technology Development Group.
October 1978. 38 p.

Population growth, cash cropping as a result of a market economy etc., an outcome of colonialism in third world countries are partly responsible for the firewood crisis in these areas. As fuelwood becomes scarce, people resort to using wood from live trees as also using other biomass fuels such as dung, crop residues etc. To develop design creteria for fuel efficient stoves, it is necessary to determine the peoples priorities in using fuel, what their current cooking and heating methods are, and general cultural considerations affecting acceptability of alternative designs. Traditional wood burning stoves are not very efficient compared to charcoal stoves which are much more efficient and

durable. A questionnaire sent to over 80 individuals and organisations for establishing design criteria for improving stoves designs showed that factors such as low maintenance, high durability, low cost, use of local materials, and a fairly high efficiency appeared to be the generally favoured criteria. Several examples have been given as guidelines for considering the socio-cultural values of people before a technically well desinged stove is introduced in a particular area.

A brief description of six models of charcoal stoves from Indonesia have been given. They are mostly made of fired clay and refractory and their efficiencies of four of them are in the range of 27 to 36 % with a few modifications in some cases.

10. Domestic Chullah.
Calcutta, Coal India Ltd. mimeo.

Increased use of soft coke and coal as cooking fuels can help conserve scarce firewood. Since existing domestic ovens have several deficiencies the most important being the non utilization of volatile therms, a national competition was organised by CIL for improving the existing designs. From the entries received, four designs considered to be the best have been described.

In one design, a chimney cum burner is kept on a commonly available bucket chula and the volatile gases are burnt in the burner. In the other designs, the coal is first converted to semi coke in an annular chamber and is used as the main feed in the central chamber for the subsequent charge.

11. Economic stove that burns sawdust as fuel.
Eric Simon and Pedro Solis.
Appropriate Technology. 4, 1; May 1977; 23-4.

Describes a stove that can be fabricated out of a 5 gallon can using sawdust as a fuel. Four holes are made at the bottom of the can and broomsticks are positioned into it so that when sawdust is compacted into the can, and the broomsticks removed, the four ducts act as flue passages. A chimney with a reducer duct is welded on to a window on the top of the can and acts as a smoke outlet. The flame is started by sprinkling a few drops of oil ignited by a large wick. A grill placed on the can supports the cooking pot and forces exhaust gases through the chimney. A 2kg charge of sawdust gives about 4-5 hours of good cooking fire.

2. Energy requirements for household cooking in Africa with existing and improved cooking stoves.
Keith Openshaw
Tanzania. University of Dar-es-Salaam. April 1980.

It is estimated that by or before the turn of the century, demand for wood will outstrip the renewable supply and the trend could be halted by more intensive forest management and introduction of more efficient cooking stoves. In rural areas of Africa, cooking is done on open fires with an efficiency of 7 to 8 % only. In urban areas, metal charcoal stoves having around 15 % efficiency are used. Two improved stove designs are described, one using wood as fuel developed by ITDG, London, having an efficiency of 15 % but which could be improved upon with slight modifications and the other, a clay stove using charcoal and commonly used in Thailand which gives an efficiency twice as that of the traditional metal stove. Alternative renewable energy sources are examined, but it is concluded that the greatest gains will be achieved by concentrating effort on improving stove designs and by more intensive forest management.

13. Energy: Wood, sawdust and rice hull stoves.
Appropriate Technology Sourcebook.
Volunteers in Asia 1976; 176-77.

Describes stoves made of used oil drums using sawdust or ricehull as fuel. An air vent is cutout at the bottom side of the drum and two thick pieces of wood are placed at right angles to each other, one in the center of the drum and the other through the air vent. When sawdust is compacted and the wood pieces removed, a flue passage is formed. A narrow stick dipped in kerosene is ignited and pushed through air vent to start the fire. A full chamber of rice hulls and a one metre length of wood 2 cms in dia can provide a cooking flame for 2 hours.

14. Evaluation of chulas. (B. Tech. Project Report).
N. Jajodia.
Bombay, Indian Institute of Technology. March 1980.

The properties, production and procurement aspects of various fuels such as firewood, charcoal, coke etc have been considered. Both traditional and improved chula designs have been discussed. A detailed experiment has been carried out for evaluating the performance of these using the boiling cycle test with coke and charcoal as fuels. The efficiency has been defined by

$$\eta = \frac{\text{Useful heat gained in heating water}}{\text{heat supplied}}$$

$$= \frac{\text{latent heat of steam} \times \text{quantity of water boiled off}}{\text{calorific value of fuel} \times \text{quantity of fuel burnt}}$$

The maximum efficiency was found for the mud coated bucket type chula (15.3 %) using charcoal as fuel and 17.7 % for the sheet metal chula using coke as fuel. A heat balance estimate has also been given. A users survey carried out indicates that designers should concentrate on improving existing designs rather than go for entirely new designs.

5. Family cooker. Instruction how to make and use them.
J.C. Overhaart.
The Netherlands. Dept. of Appropriate Technology.
Eindhoven University of Technology. 1979. 31p.

Complete instructions illustrated with line diagrams have been given on how to make the family cooker and use it. The stove is made of sheet metal with a combustion chamber, a flue chamber and a chimney. Cooking is done in a pot placed on the combustion chamber unit, while a pothole in the flue chamber serves for warming water. A metal grate is used for burning the firewood which needs to be fed in small pieces. Vents on the combustion chamber sides below the grate level, help in air circulation. A draft regulator is provided in the chimney. Directives have been given for using alternative materials for making the components in case the standard recommended material is not available.

6. Fuel conservation in domestic ombustion.
K.S. Salariya
(College of Agricultural Engineering)
Punjab Agricultural University, mimeo.

Describes improvements incorporated in traditional chulas (wood stoves) and angethis (charcoal stoves) commonly found in India with a view to improve their efficiency. The traditional chula is a semicircular single pot stove having a mild steel reinforcement. This has been modified in two stages: first by incorporating a fire grate and stand for better combustion and ash removal and secondly incorporating a steel water jacket to recover heat from the clay walls which would otherwise be wastefully dissipated. For the angethi, the first modification is provision of a chimney attached separately to the stove for smokeless operation and secondly, water jacketing the walls of the stove as well as the chimney for recovering wasted heat. Experiments on all the models showed that the modified chula with a fire grate had an efficiency of about

14 % in addition to 9.2 % heat recovered from the water jacket and for the modified angethi the values were 8.4 % and 11.87 % respectively.

17. Fuel efficient, smokeless stove for Rural India.
Gyan Sagar.
Appropriate Technology. 7, 2; September 1980; 31.

Describes a modified version of the chula developed at the Planning Research and Action Institute, Lucknow. It can be made with mud or bricks and without the help of a trained mason; it incorporates two pot seats, one coming directly above the firebox and the other located either behind the first one or by the side of it. A flue passage from the second pot seat leads to the chimney. A damper for controlling the draft is located just before the chimney.

Twenty five chulas were installed in a village and a survey carried out a yeat later showed that 22 were working satisfactority, two families having left the village and one chula damaged while the thatched roof was being replaced.

18. Helping people in poor countries develop fuel saving cook stoves.
Federal Republic of Germany, German Appropriate Technology Exchange (GATE). October 1980. 148 p.

The purpose of the mannual is to emphasize not so much the construction methods for specific stove models, but the whole complex question of how poor people can be helped to develop solutions to their problems in relation to the firewood crisis. Part one explains ways of working with the villagers to design stoves: getting first hand information on the local customs, fuels available, foods and cooking practices and so on. A socio cultural and technical checklist have been provided. Examples explain the role of the development worker in introducing and promoting stoves. Accent is placed on

the "evolution model" rather than the "consumerist model" which is more applicable for promoting mass produced goods. Various methods of disemination have been given and the needs and methods of training stove builders. The technical information in part two gives pointers for selecting, designing and testing stove systems. Building instructions have been given for several stove models along with advantages and disadvantages as well as ideas for improvement.

19. How to make an oil drum stove.
New Guinea, South Pacific Appropriate Technology Foundation (SPATF)

This a fully illustrated step by step construction for making a woodburning stove using an oil drum. One end of the drum is cut out and holes punched into it so that it serves as a grate. Windows are cut out at the bottom of the drum for air intake and an opening is provided near the top for the fire box. A hinged door is also provided. A pipe with its bottom portion cut to form a 'V' is inserted through a hole on the stove top. This serves as a chimney.

20. Improved Cookstoves in Upper Volta.
Elisabeth Gern and others.
Federal Republic of Germany, German Agency for Technical Cooperation. July 1980. 115p.

The report comprises of the findings of four years of work related to cookstoves in six different places in Africa. It includes a description of the traditional 3 stones fire used for cooking, the fuels used, types of cooking vessels, the various foods prepared and other uses of a fire. Several designs of traditionally used stoves have also been described. Among the improved designs of cookstoves discussed are the Nouna stove developed by the German Forestry Mission and the Kaya stove developed by Jonathan Hooper, a Peace Corps

Volunteer. General recommendations have been made regarding successful implementation of a stove program suited to Upper Volta in particular. These include developing local ingenuity in using skills available with local people, diversification of stove models already in existence such as the Louga stove, the Lorena stove, the Hyderabad chula and the Feu Malgache; using many ways to introduce stoves and starting regional stove centres for the purpose of demonstrations of working models, experimentation and testing, formulating training programes and organisation of follow-up studies and processing feedback from the villages. Experiments have been conducted on all the stoves discussed to evaluate them for their performance in terms of wood savings.

21. Improved hearths to battle the firewood crisis.
Dhammika de Silva
CISIREACH. 2, 4; October 1980; 3-5

About 80-90 % of households in Sri Lanka depend on firewood as a fuel for cooking. Excessive demand of this limited resource has created desertification problems in some areas. Solutions to this are being worked out at two levels: (1) by tree planting campaigns organised by the Government as well as some communities and (2) by designing improved cooking stoves which are fuel efficient.

The CISIR stove is made entirely from a sand/clay mixture and comprises of a fire chamber with a pot placed directly over it and subsequent pot holes (two in number) located on a stepped platform with a rising flue passage to extract as much heat as pollible before the gases leave the chimney. In addition, 2 potholes are located adjacent to the first one for heating water and a chamber below the chimney can accomodate a hot water tin can. Below the flue

passage is a drying chamber heated by the flues for preserving fish and dried fruits.

22. Improving solid fuel cooking stoves with special reference to the Family cooker.
P.P. Attwood.
The Netherlands, University of Technology Eindhoven.
August 1980. 89p.

Gives a detailed account of investigations done on improving the effectiveness of the Family Cooker. A novel approach to the concept of efficiency is outlined. The effectiveness of cooking food depends on the amount of fuel required to maintain boiling water simmering for the full cooking period. Thus, fuel economy, a more practical measure of effectiveness for cooking stoves has been defined and is taken as the actual amount of fuel burnt whilst simmering the water. The effective fuel burnt is the fuel equivalent of the pan losses. Thus cooking stove efficiency is the ratio of fuel burnt effectively to the fuel economy. Several experiments on the Family Cooker based on variations of different parameters such as air inlet, chimney diameter, combustion chamber etc., have been described. Results of these tests have also been plotted graphically. The best overall combination of air inlets and chimney size was found to be 300 mm^2 air inlet area and 72mm chimney diameter. The best cooking stove efficiency was obtained with the following ratios:

- chimney area/air inlet ratio = 13.56
- chimney area/fire grate air holes area ratio=0.97
- fire grate air holes area/cooker flue duct area ratio = 4.25
- fire grate air holes area/hot box flue duct area ratio = 2.45

- chimney height/diameter ratio = 56

The efficiency of the stove improved by incorporating changes in the components as follows :

- insulating the cooker unit with glass wool improved the efficiency by 15 % in one experiment
- insulating the hot box gave a reduction in heat lost by 15 %
- increasing the air flow ratio of outlet/inlet area from 9.8 to 13.6 improved the efficiency by nearly two and a half times
- using a double pan (aluminium and glass) instead of a single aluminium pan with lid reduced heat lost through evaporation by more than ten times.

23. Lorena Owner Built Stoves.
Ianto Evans.
Volunteers in Asia. Jan. 1979. 96p.

The book is a construction manual for the Lorena stove developed at (Choqui Experimental Station, Guatemala and Aprovecho Institute, Oregon. Built without any special tools and, at almost no cost, the stove is made of mud and sand incorporating dampers for combustion control and a chimney for smoke outlet. Stove sizes vary depending on requirements but approximately measure 1m x 1.3m x 1m. A number of potholes are available for cooking, all connected by flue passages which are offset so as to give a whirling effect to the hot gases and therby improve convection, and mounds (risers) are provided at the bottom below the pot holes to direct hot air towards the pot. These features and a high thermal mass make the stove 50% more efficient than traditional cooking arrangements. A variety of cheap

fuels can be burnt and the stove can be used for cooking in a standing position. A socio cultural assessment of the stove and its diffusion in highland Guatemala has also been included. A study indicated an overall high level of acceptance of the stove. Primary advantages perceived by majority of the families interviewed included reduction of smoke in the kitchen, savings in firewood, ability to cook in the standing position, reduction of effort in cooking, constant availability of hot water and aesthetic qualities of the stove. Some of the disadvantages mentioned were: inability to provide space heat and inflexible nature of the cooking surface. The Estacion Experimental Station promotes the stoves by giving stove building courses, disseminating pamphlets, holding exhibitions etc. Research in design and use is also undertaken but it is recommended that local people should participate in this crucial innovation process.

24. Magan chula: A smoke free cooking oven.
Wardha. All India Village Industries Association. 1953.

Describes the chula developed at Maganwadi, the head quarters of the All India Village Industries Association. The document is a complete mannual on construction of the chula, its installation and use. The chula comprises of three potholes in a triangular configuration, one pothole coming directly above the fire. Materials used for construction are clay, horsedung or fibrous material. Iron has been avoided as it is expensive and may not be available in villages.

Flues are provided as passages for hot gases. A damper located before the chimney regulates the combustion. The chimney is made of clay pipes. Constructing the chula takes about 8 hours and time for installation by two persons is about 4 hours. Several advantages of the Magan chula over the country

chula have been enumerated. The only disadvantages mentioned are the large space requirement, cost of construction, skilful use and inflexible design for accomodating different pot sizes. Draft problems caused by wind on the cowl pipe and means to avoid them is also given. Figures depicting the chula and the tools required for its construction, a sectional dimensional drawing and drawings for cowl assembly and dampers, rings etc. have also been included.

25. Nasinu Wood Burning Stoves: A preliminary report.
A. Weir and J. Richolson.
Suva Fiji, Utilization Department, Fiji Forestry Department and Institute of Natural Resources, University of South Pacific. August 1980.

Prototypes have been built of eight different designs of wood burning stoves. One is the Indian chula built in two halves with concrete. The others are Nasinu stoves all built from concrete and cast iron with a modular construction. The Mark 'IV a' design is similar to the Indian chula except for modular components and the firebox with a cast iron door, raised grate and air control valve. In Mark 'IV b' cast iron discs with fins extending into the burning gas stream are inserted in the holes to improve heat transfer to pots of any size. The Mark V has also two cast iron hot plates for the top and a shorter flue. Mark VI includes a longer firebox and introduces the principle of secondary combustion. Since early trials were unsuccessful, further work was cancelled. Mark VII is a two pot stove with a firebox door and grate. The last was a cast iron two pot stove available commercially in New Zealand. Detailed tests were carried out on all the stove to evaluate their performance on the basis of which the Mark 'IV a' was found to have the greatest thermodynamic efficiency, (between 12.8 and 15.1%). All the stoves were smoke free and used substantially

less wood than an open fire. Two stoves have been recommended for further development: an improved chula being a simplified (cheaper) version of the Nasinu Mark 'IV a', featuring modular construction, a shallow flue and some form of air control; the second, a modified version of Mark VII with features for grilling and baking.

26. New Jiko.
Bollag Burton.
Development Forum. 8, 2; March 1980; 10.

Describes the New Jiko developed by Waclaw Micuta of the Bellerive Foundation. The stove has a higher efficiency compared to the traditional Jiko because of the following features:

- the cooking pot is placed inside the stove instead of on top of it
- air venting is better
- exterior wall is insulated
- interior design forces heat around a larger surface of the pot.

These factors combine to produce a hotter fire with more complete combustion and greater concentration of heat on the cooking vessel. In addition, cheap fuels such as straw, leaves, corncobs etc. can be used after compressing them into briquettes.

27. New Nepali Chulo.
Kathmandu, Research Centre for Applied Science and Technology (RECAST) Tribhuvan University. 1980; 35p.

Traditional cooking arrangements in Nepal normally consist of 3 stones, an iron tripod or made of mud and/or stones. To overcome the drawbacks of health hazards and smoke emission, the Centre has designed a number of stoves on which field trials were conducted with encouraging results. The basic design is a three pot-hole model in an 'L' shape. It has two dampers, one between the firebox door and the first pothole and the chimney. The materials used are either brick and clay or mud and sand (1:4). The pots sit slightly exposed to the flues in the flue passage and the stove base is raised towards the chimney to direct hot gases to the pots. Three other models are also illustrated, one model having four potholes and the remaining two with three potholes. The top plates are prefabricated in all three models and the chimney is located outside the dwelling. Different ways of fixing the chimney, its fabrication from sheet metal, cleaning methods as well as dimensions of appliances such as the dampers, grate etc have been illustrated.

28. Optimum use of firewood and firewood substitutes.
Waclaw Micuta.
ICVA News. (Special report) No. 85. April 1980.

Solving the firewood crisis in rural areas of Africa as well as other parts of the world where cooking is done on an open fire with thermic efficiencies hardly exceeding 3 % calls for the following measures to be taken:

- introduction of metal, clay or brick stoves having features such as
  - combustion retained inside the stove with combustion chambers for wood stoves being at least 20 cms high and in the shape of an open cone
  - reducing heat losses in the stove

- use of cast iron pots lowered into the stove
- use of alternative fuels such as hay, straw, weeds, coffee husks etc. and slowing combustion by compressing them into briquettes
- use of hayboxes for keeping the food warm etc.

The New Jiko is an improvement of the traditional Jiko, a charcoal stove commonly used in Africa. It uses only half the charcoal compared to the traditional model. An improved sheet metal Jiko developed by J. Jankzak of Poland has also been illustrated. It has a double lining uses preheated air and a combustion chamber in the form of a cone.

30. Preliminary testing of wood consumption in four "smokeless cooker" models and the traditional three stones fire.
Whitney Gaberson.
VITA, 1979. mimeo.

Simple tests have been described to evaluate the fuel efficiency of some models of brick, cement and earthen cookers built in Upper Volta as well as the traditional "three stones" stove. All the tests incorporate bringing water to a boil and noting the actual consumption of wood. The time taken to boil the water in two pots is also noted. Surprisingly it was found that the performance of the three stones stove was better compared to the four stove models described.

31. Report on the mud stove program as carried out at the Rural Industries Innovation Centre, Kanye Botswana.
A Nkwe.
Botswana, Rural Industries Innovation Centre. August 1980. 14p.

Examines the mud stove program introduced in Botswana in 1977 and continued over a period of theree years. Five different types of stoves were built and tested and introduced to the villagers after demonstrating them and training the villagers to build them. However the mud stoves were not being accepted. Detailed testing of the stoves showed that only a small amount of firewood is saved compared to an open fire if the stoves are cold when the fire is started. Improvements gained by preheating the stoves did not match the traditional ways of cooking.' It was also felt that stoves do not provide a meeting place for the villagers as does the open fire which is also simple in appearance compared to commercial stove designs. It is suggested that work should be done to build simple stoves which could provide savings in firewood above 50% when compared with an open fire even if the stove is cold at the time cooking begins.

32. Smokeless HERL chula.
Hyderabad. Hyderabad Engineering Research. Laboratories. 1956.

In order to alleviate problems created by smoky chulas and the direct heat of a blazing fire, a new type of smokeless chula was designed by Dr. S.P. Raju the first Director of the Hyderabad Engineering Research Laboratories. It comprises of of a simple structure which can be built of brick and mud or only mud plastered with fine earth, and has an 'L' shaped duct with three holes for cooking pots and an opening for firewood. An adjustable damper for combustion control has been provided after the hot water pot hole. The chimney for smoke outlet can be made of tin, GI Sheets, guna tiles or pipes of clay or asbestos. The opening for firewood is 8½" x 4½" enough for a family of six to eight persons. Sectional diagrams have been given for the stove along with details of operation. Special features emphasising its simplicity, hygienic operation and economy aspects have been highlighted.

33. Smokeless stove: Ghana : Case study No. 7.
Canadian Freedom from Hunger Foundation Ontario and
Brace Research Institute, Canada.
Appropriate Technology Handbook, 1976; B 7.1 - B 7.6.

Describes a stove constructed from clay or laterite as the major building material with a few pieces of reinforcing metal rods and bush sticks to strenghten the stove top. The stove has an 'L' shaped flue duct with three potholes for cooking and one for heating water. A dome shaped oven is connected to one side of the stove and can be used for baking. A damper located between the last pothole and chimney regulates the draft and another damper between the oven and first pothole can be shut when the oven is not in use. The construction of the stove is illustrated in a step by step manner with the help of diagrams. Advantages of the stove include possibility of cooking in a standing position, multiple potholes, provision of an oven, draft control and smokeless operation.

34. Some performance tests on open fires and the Family Cooker.
K. Krishna Prasad Ed.
The Netherlands, Technical University of Eindhoven.
June 1980. 23p.

Systematic studies on open fires under laboratory conditions have been described which show that remarkably high efficiencies close to 28 % can be obtained, a value much higher than that normally quotated for open fire efficiencies under field conditions. Important parameters affecting the efficiency are : height of the pan above the base of the fire, moisture content of the wood and use of a grate.

Experimental details of tests conducted on the Family Cooker have also been described in detail and the efficiency is shown to vary between 21 to 34 %. Heat balance estimates have been worked out which shows that heat losses from pan sides account for about 8% of the total heat input and can be minimised by sinking the pan inside the combustion chamber.

Secondly, insulating the sides of the combustion chamber reduces heat losses by 14 % but most of the heat is carried away by combustion gases. Flue box losses account for a sixth of the heat input and can be reduced by introducing a second pan in the flue gas stream. Carbon monoxide also accounts for a sixth of the fuel used up. Increasing the combustion volume reduces the formation of carbon monoxide but increases heat loss. Suggestions have also been made on important parameters to be considered for further investigations.

35 Standard method for determining the efficiency of a fuelwood of charcoal stove.
Dhammika de Silva (Wood and Cellulose Technology Section, Ceylon Institute of Scientific and Industrial Research, Sri Lanka). Personal Communication.

A simple method for determining the efficiency of a stove has been described. A fixed weight of the fuel is taken and water is brought to a boil in multiples of 2 litres until all the fuel is utilized. Aluminium pots are used and weight of water lost by evaporation is noted. Efficiency is the ratio of heat required to bring the water to a boil + the heat to evaporate the water divided by the heat content of the fuel. The heat absorbed by the cooking vessel is not taken into account because for all practical purposes that heat is not utilized.

36. Study of the problem and prospects of Biogas technology as a mechanism for rural development: Study in a Pilot area of Bangladesh.
M.N. Islam.
Dacca, Bangladesh University of Engineering and Technology. September 1980. 135p.

The study is concerned with the development of an energy assessment methodology to identify alternative energy technologies for the rural areas of Bangladesh. As such, pratical field observations have been carried out as part of the entire study on the fuel energy consumption and the heat utilization efficiencies of the different cooking devices used. The commonly used cooking stoves are the one mouth stove and the two mouth stove. Experiments have been carried out on both types using the depth of the hearth, shape of cooking pan, different varieties of firewood and the effect of a cold and hot start as variables. As a measure for improving the efficiency, both types of stoves were constructed with a chimney. Although the improved versions were experimentally found to be less efficient, the chimney provided more comfort, rendering the stove smokeless. As a next step, a modified stove (Improved Nabagram Stove) was constructed having a flue chamber leading to another pot-hole for warming water. The efficiency of this stove was better than the traditional stoves. Another version of the Improved Nabagram Stove fitted with a chimney proved it to be less efficient than the previous one although more comfortable to work with. Since cooking is done for a greater part of the year in an open kitchen yard, the improved Nabagram Stove without a chimney was considered for demonstration in the project area.

37. Study on the efficiency of the chulas.
D. Ahuja and C.N. Gupta.
National Buildings Organisation, New Delhi and U.N. Regional Housing Centre. ECAFE, 1968. 30p.
(Technical and Research Report 17)

The need for evolving suitable designs of chulas led the National Buildings Organization to carry out investigations

on existing chula designs in collaboration with the Planning Research and Action Institute, Lucknow. Data for fifty two types of chulas in use in different parts of the country were collected from various organisations and passed on to the institute which conducted systematic laboratory experiments to study relative merits of nine selected designs. Of these, two chulas found to perform in the most satisfactory manner were tested in the homes of users and their opinions obtained. The Institute finally recommended the best designs using soft coke and fire wood as fuels. The report presents details of experimental methodology including standardization of materials and equipment, different aspects such as heat efficiency, parameters affecting efficiency, assessment of performance in actual use, users opinion and recommendations etc. The South Junagadh type chula gave an efficiency of 24.72 % after modification to suit users requirements. It is conclusively stated on the basis of the tests that: clearance between vessels and cooking point decreases heat efficiency and hence should not be provided; vessels with curved bottoms give better heat efficiency than those with a flat bottom; and aluminium vessels give better heat efficiency than brass vessels.

38. Survey of wood burning stoves.
J.D. Walton Jr., <u>and others</u>.
In State of the Art of solar powered irrigation pumps, solar cookers and wood burning stoves for use in Subsahara Africa.
Atlanta, Georgia Institute of Technology. Jan. 1978; 62-71. 77.

A short history of wood burning stoves right from the use of wood for burning in the Stone Age to the Kitchen ranges presently used has been given. Among the recent efforts to develop simple wood burning stoves, one is that developed by the Brace Research Institute built from an inexpensive, mass produced galvanised bucket. The bucket, which serves to confine the fire to the area of the cooking vessel, is modified by providing an expanded metal grate about six inches from the top. The stove, costing about $ 1.50 is expected to effect a saving of 50 % of the wood required for cooking. The other design discussed in detail is the Kamado type cooker based on an ancient Japanese earthenware cooker. This is designed with a 5 gallon paint can modified by cutting a hole in the lid and a vent hole at the base of the can for draft control; two ceramic blocks or stones to support the grate, a ceramic grate with holes to support the fire and admit air for combustion; a metal grill for supporting the food being cooked. The ceramic components used are simple disk and cylindrical shapes which are easily fabricated and can be of relatively low strength. This particular stove was designed to be used in the Sahel region of West Africa.

39. Variations in chula design..
James Penfold and David Oot. mimeo.

The authors encountered considerable difficulty in boiling water on the second and third pot seats of the Hyderabad chula and hence constructed a chula with all three potseats coming into contact with the fire. The basic chula is trapezoidal in shape with potseats in triangular configuration. Materials used for construction are bricks, mud, cowdung and iron bars for reinforcement. A chimney of AC/clay pipe is also provided for smoke outlet. Variations of the stove design with features such as a stove with 4 potholes, another version to accomodate 2 large vessels etc. have been briefly explained with the help of diagrams.

40. Wood Burner's Encyclopaedia.
J. Shelton and A.Shapiro.
Vermont, Vermont Cross Roads Press. 1977.

Although a major portion of the book is devoted to the principles of efficiently designing stoves for space heating, the first five chapters are very useful to designers of cooking stoves. Concepts of energy, temperature, heat, properties and composition of fuel wood, combustion etc. have been described in a very lucid and yet technically precise manner.

41. Wood Burning (Forestry Occasional Paper I).
Hans Winklemann.
Rome, Food and Agricultural Organization of the United Nations. December 1955. 48p.

Compared with other solid fuels, wood is relatively poor in carbon but rich in oxygen. Over 80% of its heating power is derived from its volatile constituents which explains its bright and tall flame. A high moisture content reduces the amount of heat evolved and disturbs the process of combustion. Wood ash being a good fertilizer, it has an advantage over other solid fuels. The porosity of wood speeds up combustion which takes place in three successive phases. For combustion to be complete, there must be adequate air intake, intimate mixture of gases to burn completely. All these principles have been related to features of modern stoves. The second part deals with wood stoves used for heating and cooking in various contries.

42. Wood conserving cookstoves: A design guide.
Mt Rainier, Volunteers in Technical Assistance. 1979.

This design manual begins with an explanation of the basic principles of the combustion of wood, heat transfer and the various stove components. Traditionally used simple stoves have also been discussed. The various losses in a stove are analysed and methods of improving traditional stove designs using the principles of efficient combustion have been dealt with. Design features, construction, use and maintenance information for the Lorena, 'smokeless chula, the Singer Stove and Sawdust Stoves have been given. Various parameters such as choice of wood, its properties and how to use a stove most efficiently have also been explained.